Army Research Laboratory

Second Generation Weather Impacts Decision Aid Applications and Web Services Overview

by James Brandt, Leelinda Dawson, Jeffrey Johnson, Stephen Kirby, David Marlin, David Sauter, Richard Shirkey Jeffrey Swanson, Richard Szymber, and Subing Zeng

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14. ABSTRACT

Military operations and weapon systems are adversely affected to some extent by the environment, even those advertised as "all weather capable." In an effort to simplify the manner in which environmental impacts on weapon systems are determined, the My Weather Impacts Decision Aid (MyWIDA) was developed. This report documents the second generation (GEN II) of weather effects decision aids, MyWIDA, a sophisticated, rules-based expert system based on thousands of identified (and validated) weather sensitivities of Army, Air Force, Navy, Marine, and threat weapons systems and tactical operations. GEN II automatically ingests multi-day weather forecasts which are compared with system engineering limitations (rules) and identifies and provides favorable, marginal, and unfavorable weather-effects impacts in the form of a stop light chart overlaid on a map background in a four-dimensional format for the user to examine. GEN II may be tailored to specific tactical operations and missions providing detailed weather impacts information in terms of what operations and equipment are affected. GEN II also includes the Automated Impacts Routing (AIR) application, which calculates least cost paths for a user-selected system type (aircraft or ground vehicle) given a set of two or more waypoints.

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Executive Summary

The second generation (GEN II) of weather effects decision aids is comprised of a sophisticated, rules-based expert system based on thousands of identified (and validated) weather sensitivities of Army, Air Force, Navy, Marine, and threat weapons systems and tactical operations and is designed to interoperate with a routing application. Using the My Weather Impacts Decision Aid (MyWIDA) application in conjunction with GEN II's web services, it automatically identifies and provides favorable, marginal, and unfavorable weather-effects impacts in the form of a stoplight chart overlaid on a map background. This impact information can optionally be passed to the Automated Impacts Routing (AIR) web service application to determine the optimal three-dimensional (3-D) path (air or ground) through adverse weather or other obstacles. These weather impacts are based on operating limitations of friendly and threat systems, their subsystems and components, personnel, and missions with respect to time and area of operation or interest. Weather effects information (i.e., rules) are included on hundreds of military assets (both friendly and threat). Users may employ the supplied application, MyWIDA, available as a Java Application Programming Interface (API), for incorporation into existing programs or custom Graphical User Interfaces (GUIs). Additionally the application is available via web browser using either HyperText Markup Language (HTML) or Adobe Flex.* Users may also develop their own application making use of the underlying web services.

MyWIDA may be tailored to specific tactical operations and missions and provides detailed weather impacts information in terms of the operations and equipment that are affected, as well as when, where, and why they are affected. These impacts are shown on a Weather Effects Matrix (WEM), which is color coded for easy interpretation. Map backgrounds are used to overlay geographic weather impacts for particular assets (weapon systems, subsystems, personnel, etc). The user can query the application to display detailed textual weather impacts statements/explanations for a specific location on the battlefield.

MyWIDA was developed with the user in mind; using the MyWIDA web application provides an intuitive simple GUI-oriented input, while output is shown in readily understood color-coded (Red = Unfavorable, Amber = Marginal, Green = Favorable) matrices, map overlays, and succinct text statements. Users may use the existing rules contained in the Army Knowledge Online (AKO) web site's Centralized Rules Data Base (CRDB) or DCGS-A Weather's rule base located at Ft. Hauchacha or enter their own rules using Microsoft Excel† format, allowing for quick looks at alternative mission/system setups under forecast weather conditions. The forecast

* Adobe Flex is a registered trademark of Adobe Systems Incorporated.

† Microsoft is a registered trademark of Microsoft Corp. in the U.S. and other countries. Microsoft Excel is a product name of Microsoft Corp.

weather information, available from various originating centers, is ingested through a meteorological gridded data base, which automatically drives MyWIDA.

The AIR web service application, which may also be used as a stand-alone desktop application, determines the environmental impacts on systems and alternative routing options considering environmental factors along a planned path of movement. These optimal routes serve to improve survivability and movement efficiency of air and ground platforms and systems. Environmental factors which may adversely affect systems during combat operations along a projected path include adverse weather, threat activity, conflicting friendly operations, no-fly zones, and other obstacles.

1. Introduction

GEN II's technology, consisting of web services and application Graphical User Interfaces (GUIs), automates the legacy Integrated Weather Effects Decision Aids (IWEDAs) and adds a routing capability through the use of the Automated Impacts Routing (AIR) application. Because all military systems are affected by the weather to a greater or lesser degree, My Weather Impacts Decision Aid (MyWIDA) addresses weather impacts by allowing the user to select weather forecasts and assets (systems, subsystems, and personnel), coupling this information with system-specific rules, which are determined by operational usage or engineering factors, contained in the Centralized Rules Data Base (CRDB). Upon the system(s) selection and weather data ingest, GEN II/MyWIDA version (v)2 automatically identifies and provides favorable, marginal, and unfavorable weather-effects impacts based on operating limitations (rules) of friendly and threat systems with respect to time and area of operation or interest. This is accomplished by comparing the selected system's rules with the ingested multi-day weather forecast available from various Department of Defense (DOD) and national civilian sources. The comparison of the weather impacts results in a four-dimensional (4-D) "stoplight" display for the user to examine. Underlying causes for the impacts may be examined using the intuitive MyWIDA application. The user may enter their own or rules for newly developed or off-the-shelf equipment or may override the existing rule thresholds, thereby allowing GEN II/MyWIDA to be tailored to specific tactical operations and missions that provide detailed weather impacts information in terms of what operations and equipment are affected, as well as when, where, and why they are affected. This actionable weather intelligence information is then saved locally and can be used in the battlefield decision-making planning and execution processes. To examine an extended Area Of Interest (AOI), an internet connection is required to download the forecast weather data and, if the user wishes, the optional CRDB system weather thresholds.

Note: Although GEN II refers specifically to web services and MyWIDA to the application, throughout this document we refer to GEN II/MyWIDA v2 simply as MyWIDA. If, in any of the sections below, distinction between GEN II and MyWIDA is required, clarification is provided.

Atmospheric impacts on platforms and alternative routing options, which consider environmental factors along a three-dimensional (3-D) planned path of movement, of high importance during combat operations, are determined by AIR, thereby improving survivability and movement efficiency of air and ground platforms and systems. Environmental factors that are considered along a projected path include adverse weather, threat activity, conflicting friendly operations, and other obstacles. AIR's design allows it to be applied to both air and ground routing problems by its use of 4-D data grids (3-D grids over time) of impacts received from MyWIDA or other applications.

Because AIR may be accessed directly by MyWIDA or used as a stand-alone desktop application, it is discussed in a separate section of this document.

2. Background

In 1991, the Science and Technology Corporation (STC) proposed a work effort to the then Atmospheric Sciences Laboratory to integrate portions of three existing automated weather effects tactical decision aids (*1−3*) and create a new Weather Effects Decision Aid (*4−6*). In subsequent years, the U.S. Army Research Laboratory's Battlefield Environment Division (ARL/BED), along with contractors STC and New Mexico State University's Physical Science Laboratory, developed IWEDA into a powerful tool that allowed battlefield commanders and staff weather officers to query specific information regarding the effects weather has on weapon systems and operations (*7−9*). IWEDA was operationally fielded on the Army's Integrated Meteorological System (IMETS) in 2002 (*10*) and received Army accreditation, along with the associated CRDB, from the U.S. Army Intelligence Center and Fort Huachuca in 2006. In 2008 the Joint Meteorological and Oceanographic (METOC) Board (JMB) adopted IWEDA as the Joint METOC Effects (JME) standard. From late 2009 through 2010, the first version of MyWIDA technology was developed and implemented to run on Windows-based PC/laptop systems for tactical use (MyWIDA v1). GEN II/MyWIDA v2 is a completely revamped version of IWEDA and has been developed as a web service. The user can select various weather forecasts and, for the first time, can easily enter system thresholds (rules) in Excel format.

MyWIDA's focus is on users at all echelons of the battlefield, automating IWEDA's lengthy and indeterminate selection of weapon system(s), and providing the Army and other services with a user-friendly weather decision tool that assists in the selection of the best weapon systems for predicted weather conditions. MyWIDA's ability to ingest multi-day weather forecasts allows it to be used for long-range mission planning.

If weather impacts are needed for an AOI, MyWIDA will download the forecast weather data and, if the user wishes, the CRDB data base of system weather thresholds. If impacts relevant to a particular point are needed, as might be desired by Aerostat operators, the user can enter this information (local weather + rules) manually. The resulting actionable weather intelligence information, displayed spatially and temporally in an easily understood stoplight grid, can then be used in the battlefield decision-making planning and execution processes. As an example, MyWIDA's technology would have predicted the advantage of the U.S. Army over Iraqi's Forward Looking InfraRed (FLIR) systems during the sandstorm encountered in Operation Iraqi Freedom.

MyWIDA's impacts are based on an extensive data base of validated weather thresholds (*11−12*), for example, helicopters should not be launched when wind speeds exceed 40 kt.

Realizing that Commanders might wish to proceed with their mission regardless of weather conditions, the weapon system least likely to be affected can easily be selected as their primary mission system. Further, subject matter experts can easily modify existing weather impact thresholds, as well as enter new systems and/or thresholds, allowing tailoring to their local weather and mission requirements. Such tailored MyWIDA thresholds have already been developed and delivered to support Aerostat weather-related issues in Afghanistan, as well as to support the Detection of Bulk Explosives Army Technology Objective.[‡]

The AIR application is a replacement of the Army's earlier technology Aviation Weather Routing Tool (AWRT) (*13*). AIR has been developed as both a web service and as a stand-alone desktop computer application.

This is the first in the MyWIDA series of reports. The second report is a user's manual (available in draft form: contact Jeffrey Johnson at Jeffrey.O.Johnson@us.army.mil), and the third report will be a programmer's guide.

3. Rules[§]

Army regulations state that it is the policy and responsibility of the Army to determine and develop the environmental sensitivities and weather effects' critical threshold values that affect Army and threat mission areas and battlefield operating systems. Meteorological critical values are those values of weather factors (i.e., the critical thresholds), which can significantly reduce the effectiveness, or prevent execution, of tactical operations and/or weapon systems. The critical threshold is that value or point, or range of values, in which the occurrence of a meteorological element causes a significant (i.e., moderate or severe) degradation/impact on a military operation, system, subsystem/component or on personnel. Significant variations above or below the critical value can prevent the successful accomplishment of a mission. Critical thresholds define the operational limits beyond which it is not feasible to operate because of safety considerations, decreasing system effectiveness or exceeding the manufacturer's operating limits. These operational limits, referred to as "rules," are usually based on doctrine, tests conducted during weapon system development, and/or the accumulated experience and knowledge of weapon system users/operators; however, the large majority of the critical values were taken from approved military publications. Mission planners must be aware of weather factors that will affect their operations, ensuring the greatest chance of mission success. They must be familiar with meteorological critical thresholds to effectively use weapon systems and other assets and to provide maximum safety for friendly personnel. In time of war, the "critical"

[‡] Army Technology Objectives are being phased out and are being replaced with Technology Enabled Capability Demonstrations (TECDs).

[§] Due to the sensitivity of rule thresholds, the values presented here and throughout this document should not be taken as operationally correct or associated with any particular system.

meteorological thresholds are determined by operational commanders; only commanders decide which thresholds are critical for their operation, weighing the safety and efficiency factors of operations with the tactical situation and criticality of the mission. This information is used to help operational commanders make GO/NO GO decisions.

MyWIDA presents these weather impacts as a "stoplight" chart, which traditionally has had three discrete impact colors:

- Green = Favorable. Little or no impact: little or no degradation with minimal operational impacts. No weather restrictions (a GO decision).
- Amber = Marginal. Marginal or moderate impact: some degradation with moderate operational impacts. Weather that degrades or limits and is sufficiently adverse to a military operation that the imposition of procedural limitations is required. Either a GO/NO GO decision or GO with CAUTION decision. May require corrective/protective reaction or remedial action/procedure to mitigate or compensate for the impact/effect.
- Red = Unfavorable. Adverse or severe impact: significant degradation with severe operational impacts. Weather that prohibits, restricts, or impedes military operations. Generally a NO GO decision or GO with DANGER decision.

The percent degradation, or the "boundaries," for the three impact regions was taken from Army Field Manual (FM) 34-81-1 (*14*). Table 1 presents the impact criteria, and figure 1 graphically presents this same information for percent degradation or, conversely, percent effectiveness. All of the Army requirements, underlying assumptions, criteria, and terminology used to define the initial IWEDA rules are contained in the ARL report, ARL-TR-4672 (*12*).

Table 1. Percent degradation for the three impact regions (*14*).

Impact	Criteria
Green (Favorable)	Degradation < 25−30% or normal effectiveness > 70−75%
Amber (Marginal)	Degradation = 25−30% to 70−75% or effectiveness = 70−75% to 25−30%
Red (Unfavorable)	Degradation > 70−75% or normal effectiveness < 25−30%

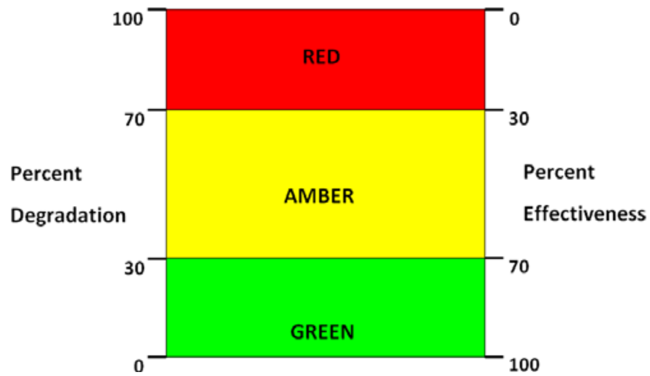

Figure 1. Impact criteria for rules.

MyWIDA operates using Boolean logic, which organizes concepts together in sets controlled by the use of the Boolean operators OR, AND, and NOT (MyWIDA does not use the NOT construct). Because MyWIDA allows users to create their own rule(s), they must follow the Boolean construct. This is the foundation by which all impacts are calculated. The reasoning behind MyWIDA having a separate Rule Evaluation Service (RES) and Threshold Evaluation Service (TES) is due to the distinction between a rule and a clause, all of which must be satisfied. An asset may have multiple rules, and each rule may have multiple clauses. For example, a rule could have only one clause as in (temperature > 100 °F) or a rule might have more than one clause as in (temperature > 100 °F AND pressure < 14 mb). Whether or not a rule contains one or multiple clauses, all of the rules for an asset are "OR'ed" together for each individual grid cell; continuing the example above, impacts might be stated as (temperature > 100 °F AND pressure < 14 mb) OR (wind speed > 38 kt).

3.1 The Centralized Rules Data Base

MyWIDA is a knowledge-based expert system (software and associated rules data base) that employs a data base of rules with associated meteorological critical values and impacts. The meteorological critical values are the lowest common denominator in assessing (1) weather support requirements; (2) specific effects of weather on any asset (system, subsystem, operation, tactic, or personnel); and (3) who has the tactical advantage in adverse weather friendly of threat forces. They are the basis upon which weather effects and warnings/advisories are established and are the bridge or connection between the battlefield weather and its warfighting operational impact. An accurate, complete data base of critical threshold values for both friendly and threat capabilities are a key ingredient for Army weather operations.

The robustness of MyWIDA, and its predecessor IWEDA, are limited by the quality and completeness of its knowledge rule base. Currently, over 15,000 rules based on military meteorological critical values and impacts have been collected, developed, and cataloged by ARL for Army, Air Force, and Navy systems, subsystems, components, tactical operations, tactics, personnel, and friendly/threat weapons systems. The legacy Rules Repository (RR) CRDB is currently hosted by ARL on the Army Knowledge Online (AKO) web site; DCGS-A

Weather will maintain the official site at Ft. Huachuca (*15*). Details on the development, structure, maintenance, and utilization of the rules' critical values data base can be found in the Army Weather Effects Critical Values Data Base (*16*).

Based on the legacy IWEDA hierarchy structure, the CRDB contains rules for military assets (system, subsystem, operation, tactic, or personnel). Most of the meteorological critical values established in this data base are a compilation of validated critical values and impacts taken from a vast number of approved military publications, for example Army FMs and operator/system Technical Manuals (TMs). The primary sources of validated information used to develop the meteorological impacts and critical values are the Army's published (approximately) 550 FMs and 11,000 TMs. Other important secondary sources for critical values and impacts are input from surveys of Army Battlefield Functional Area (BFA) proponents (i.e., Army branch proponents and BFA at the TRADOC Centers and Schools); available compilations from third-party sources, for example United States Special Operations Command (*17*); the Army Test and Evaluation Command (ATEC) ranges, proving grounds, and facilities; Army weapon systems' Program Manager (PM) offices and industry contractors; and the systematic analysis of weather-induced degradation of operations, systems, and personnel.

Finally, there is usually a 5−10 year time lag from when a new system is fielded to when validated meteorological threshold values and impacts are documented in officially approved doctrinal publications for use in rules' development. Thus, the MyWIDAv2 default rules set provides only a "starting point" list of unclassified/for official use only (FOUO) meteorological critical threshold values and impacts for typical tactical operations, various platforms, and weapons systems and by no means represents an all-inclusive or comprehensive list of thresholds and impacts. Especially with respect to weapons systems and platforms, the associated rules are for systems generally 10−20 years old. For this reason, the MyWIDAv2 default rules set does not include newer weapons or systems employed in the field; however, MyWIDA does allow the user to enter their own rules.

3.2 Usage

Legacy IWEDA used the Rules Encoding Application (REA) (*18*) to display, edit, and manage the rules contained in the CRDB using a hierarchy of assets comprised of systems, subsystems, and components. However, this structure does not allow a quick determination of which cell in a particular layer impacts a selected asset. For example, the Apache may have the Target Acquisition and Designation Sights (TADS) fitted, and the TADS itself is comprised of various sensors. For legacy IWEDA, the Apache would be the system, the TADS would be the subsystem, and the sensor would be the component. Using that structure, the user would first have to examine the Apache system, then the TADS subsystem, and then the component sensor(s) to determine that, say, the weather may have impacted one of the sensor's ability to "see" under the forecast weather conditions. Thus, MyWIDA considers all entities to be "assets," showing the impacts of each asset independently on the WEM and/or the map overlay.

The seven essential pieces of information required to define a MyWIDA rule, which must appear below the header (row 1), are (1) the name of the asset of interest (weapon, system, tactical operation, etc.), (2) a unique “rule” ID related to the asset, (3) the meteorological parameter causing the impact on the asset, (4) the arithmetic operator, (5) the meteorological critical threshold value, (6) the associated units of measurement, and (7) the impact code (Red = 2 or Amber = 1). Note that the columnar input is *case dependant* but *order independent* and must be on one row. Table 2 is an example of the MyWIDA rule for a tracked vehicle, showing the seven essential pieces of information used to define a rule. A “rules” template and additional examples may be found in the user’s manual.

Table 2. IWEDA rule example showing information needed to define a MyWIDA rule.

Asset Name	**Rule ID**	**Impact Code**	**Parameter Name**	**Critical Value**	**Operator**	**Units**
Tracked Platform	1	2	Visibility	800	<	Miles

4. Weather Forecast Models

MyWIDA currently employs a number of weather models from which impacts on assets are derived. These weather forecasts, available from various originating centers with differing resolutions, are presented in table 3. Additional models will be added in the next version. A brief discussion of the weather forecast models available in MyWIDA follows.

Table 3. Various originating centers and their available forecasts in MyWIDA.

Available Model(s)	**Available Resolution**	**Originating Center**
GFS	2.5, 1.0, and 0.5°	NCEP AFWA
WRF	$\leq$ 45 km	AFWA
	1 km	Dugway Proving Ground (4DWX)

4.1 The Global Forecast System

The Global Forecast System (GFS) (*19*) is a global numerical weather prediction computer model run by the National Oceanic and Atmospheric Administration/National Centers for Environmental Prediction (NOAA/NCEP). This model is run four times a day and produces forecasts up to 16 d in advance but with decreasing spatial and temporal resolution over time.

The model is run in two parts: the first part has a higher resolution and goes out to 192 h (8 d); the second part runs from 192 to 384 h (16 d) at a lower resolution. The resolution of the model varies: horizontally, it divides the surface of the earth into 35 or 70 km grid squares; vertically, it divides the atmosphere into 64 layers and, temporally it produces a forecast for every third hour for the first 192 h; after that they are produced for every 12th h. The GFS is also used to produce model output statistics, in three ranges: every hour for 24 h, every 3 h out to 3 d, and every 12 h out to 8 d.

4.2 WRF

The Weather Research and Forecasting (WRF) Model (*20*) is a next-generation mesoscale numerical weather prediction (NWP) system designed to serve both operational forecasting and atmospheric research needs. It features multiple dynamical cores (Advanced Research WRF [ARW] and Nonhydrostatic Mesoscale Model), a 3-D variational data assimilation system, and a software architecture allowing for computational parallelism and system extensibility. WRF is suitable for a broad spectrum of applications across scales ranging from meters to thousands of kilometers.

4.2.2 4DWX

The 4-D Weather (4DWX) model is a result of collaboration between the National Center for Atmospheric Research (NCAR) Research Applications Laboratory (RAL) and ATEC (*21*). 4DWX's primary model core is the WRF (*20*) model, although the Fifth-Generation Mesoscale Model (MM5) (*22*) is still used. RAL can tailor the model used in 4DWX for a particular region, for example by adjusting the number of vertical model levels available. 4DWX, executed at Dugway Proving Ground, Utah, is used at these Army ranges: Cold Regions Test Center, Alaska; Yuma Proving Ground and Electronic Proving Ground, Arizona; White Sands Missile Range (WSMR), New Mexico; Redstone Test Center, Alabama; Night Vision Laboratory, Virginia; and Aberdeen Proving Ground, Maryland; one other site serves as a backup by also hosting 4DWX model runs. The data ingest core of 4DWX is the Real-Time 4-D Data Assimilation (RT-FDDA) system (*23*). RT-FDDA uses modifications to an NWP model's predictive equations, which permit the model to be gently adjusted, or nudged, toward observed conditions during the analysis state. The scheme is computationally efficient and preserves the precise timing of observations, which gives 4DWX a more accurate depiction of the weather at any instant. WSMR 4DWX WRF model runs occur at 0000 UT, 0600 UT, 1200 UT, and 1800 UT with a forecast length of 72 h. 4DWX model grid resolutions ingested into MyWIDA are 10, 3.3, and 1.1 km.

4.3 Postprocessing Algorithms

The models do not provide all of the parameters necessary to evaluate the CRDB rules. Therefore, the model data from originating centers (see table 3) are expanded through postprocessing. This postprocessing, used to produce forecasts for parameters that are not

calculated in the NWP model, such as probability of precipitation, visibility, probability of lightning, etc., incorporates standard AFWA/NCEP and ARL algorithms.

The MyWIDA surface and upper air parameters,[**] which the associated rules are based on, are listed in table 4. That table shows which parameters are postprocessed by standard AFWA/NCEP model algorithms and which parameters are postprocessed by algorithms developed by ARL. Specific details on the ARL developed postprocessing model algorithms can be found in the references cited for a particular parameter of interest.

Table 4. Summary of postprocessed parameters.

Parameters	**Level**	**Parameters**	**Level**
Cloud Ceiling	Surface (*24*)	Precipitation Accumulation	Surface (*26–27)*
Cloud Cover	Surface (*24*)	Rain	Surface (*26–27)*
Cloud Layer Amount	Upper Air (Aloft) (*24*)	Relative Humidity	Surface (*26–27)*
Dewpoint Temperature	Surface and Upper Air (Aloft)	Snow	Surface (*26–27)*
Fog	Surface (*25*)	Snow Depth	Surface (*26–27)*
Freezing Rain	Surface (*26–27)*	Surface Elevation	Surface
Hail	Surface (*26–27)*	Surface Gust	Surface
Heat Stress/Casualty	Surface (*28*)	Surface Temperature	Surface
MSL	Surface and Upper Air (Aloft)	Surface Wind Speed	Surface
AGL	Upper Air (Aloft)	Thunderstorm (Probability)	Surface (*24*)
Icing	Upper Air (Aloft) (*24*)	Turbulence	Upper Air (Aloft) (*24*, *30*)
Illumination	Surface (*29*)	Visibility	Surface (*24*)
Inversion Height	Surface (*24*)	Upper Air Temperature	Upper Air (Aloft)

[**] A surface observation is a meteorological observation made on the Earth's surface in contrast with an upper air observation, which is an observation made in the free atmosphere either directly or indirectly.

Table 4. Summary of postprocessed parameters (continued).

Parameters	Level	Parameters	Level
Low Cloud Base Height	Upper Air (Aloft) (*24*)	Upper Air Wind Speed	Upper Air (Aloft)
Pasquill Categories	Surface (*24*)	Wind Chill	Surface (*26–27)*
Precipitation Rate	Surface (*26–27)*	—	—

4.4 GMDB

The Gridded Meteorological Data Base (GMDB) is the postprocessed data base that MyWIDA uses. The GMDB schema (see figure 2) models the atmosphere in 4-D by horizontal grids of weather parameter values at numerous vertical layers, which are dependent on the selected forecast model, over a number of regularly occurring forecast times. It imports the following schema from the joint METOC model: the JMG_GridPrjctn is the map projection, the JM_Layer is the atmospheric layer, and the JM_MasterParameter is the parameter information, respectively (*31*).

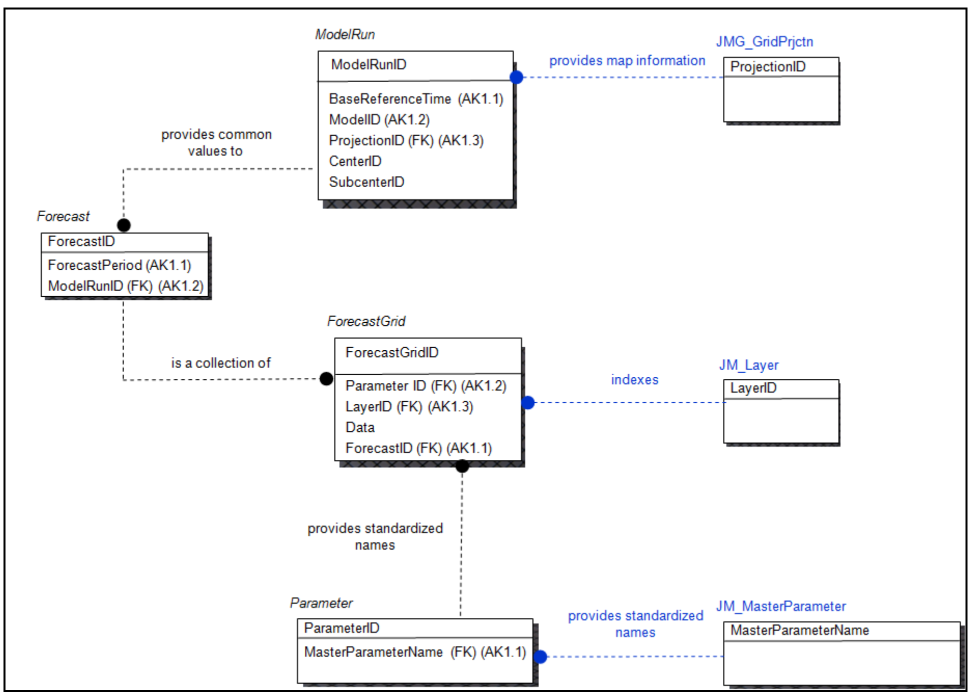

Figure 2. GMDB schema.

Referring to figure 2, the *ModelRun* is the root of the GMDB schema and represents metadata that applies to all forecast grids, such as the base reference time of the forecast, the projection information, and the forecast center of origin. The *Forecast* is a collection of the model run's

forecast times. The *ForecastGrid* contains the forecast values indexed by parameter, layer, and forecast time. The *Parameter* provides standardized master parameter names.

5. GEN II Web Services

GEN II is comprised of a collection of web services and the MyWIDA, and the Area Of Interest web applications (AOI app). These web services are defined by interfaces described in the Web Services Description Language (WSDL). Other systems interact with these web services in a manner prescribed by their description in Extensible Markup Language (XML), using the Simple Object Access Protocol (SOAP), conveyed with Hypertext Transfer Protocol (HTTP). The four web services, discussed below, are the Area Of Interest Service (AOIS), the TES, the RES, and the Impact Overlay Service (IOS).

5.1 Area of Interest Service

The AOIS defines and makes available areas of interest, managing requests for weather data from multiple originating weather forecast centers. These centers and their available forecasts and resolutions are presented above in table 3.

The AOIS is responsible for accepting data requests, scheduling the required processes and producing the requested data. After the user has submitted the data request, the AOIS acquires, ingests, and postprocesses this forecast data into the GMDB. Data orders placed into the data base (UserOrder) include information, such as user ID, area name, originating center, model, content of the request, and processing date/time, etc. The AOIS job scheduler then monitors and keeps track of the incoming/existing order, updating its status for each stage over the course of this whole process.

The following describes the methods:

- newOrder−submits an order for a given user ID and AOI request object which contains forecasts, projection, model, layers, and parameters.
- deleteOrder−removes an existing order for a given user ID and area name.
- queryOrder−returns information containing job details and AOI request details for a particular order for a given user ID and area name.
- getJobDetails−returns an list containing information such as job completion time, order status and model run ID, for a given user ID.

5.1.1 AOI Web Client Application

The AOI app, implemented with HTML/Javascript/JavaServer Pages technologies, provides interfaces for defining data orders, displaying their summaries and details. The application requires a username and password assigned by the AOI app administrator (the person who is assigned to this role by the organization that hosts/maintains MyWIDA and is granted the privilege to create/manage a user account by using data base tools). These user interfaces are comprised of the following:

- AOI app Orders–provides general information concerning the order status of the AOIs.
- New Order–requests that information needed to obtain and subsequently process a selected AOI.
- Order Summary–allows the user to view/modify their order.
- Update Order–allows the user the ability to modify all the entries except the user's unique order ID.

5.2 Threshold Evaluation Service

The TES analyzes forecast data to determine where the weather thresholds are exceeded. The client supplies threshold values, that is rules, for evaluation against the gridded forecast layer data, including the surface level, over an AOI.

The primary information returned is a grid representing where the thresholds are exceeded. The grid is an array of points indicating the threshold is or is not exceeded {1, 0}, respectively. The TES also supports requests for forecast grid values and other pertinent information for the forecast. The threshold expression contains the parameter name, Boolean operator and threshold value, for example surface temperature greater than 100 °F.

The TES includes the following methods:

- getImpactMask–returns a Boolean grid (mask) resulting from the evaluation of the given threshold expression over the area of interest, forecast, and layer.
- getGridInfo–provides meta-data for available forecasts, including projection data, model runs and forecast periods, layers, and parameters.
- getParamValue – returns the value of the parameter for the given forecast, layer, and point.
- getHeightMSL – returns the grid of height above sea level for the given forecast and layer.
- getForecastGrid – returns the grid for the given parameter, forecast, and layer.

5.3 Rule Evaluation Service

The RES provides asset impact grids by evaluating a set of rules for specified forecasts and levels.

Given a list of assets, and their associated rules, the RES first disassembles the rules into a collection of independent clauses (c.f. section 3), which are sent to the TES for evaluation. The TES clause evaluations are then combined by RES into asset impacts.

The service does not include a collection of assets and their associated rules: the rules must be included in each request. RES is also stateless: each request is treated as an independent transaction unrelated to any previous request. This results in a simple, efficient service, which can support multiple users, each with its own local rules.

The RES supports only one method: EvaluateAsset, which returns a collection of 3-D impact cubes for the given list of assets, rules, forecasts, and layers. For each asset and forecast, there will be one impact cube containing multiple two-dimensional (2-D) impact grids, one grid per layer, consisting of the highest impact at each grid cell.

5.4 Impact Overlay Service

The IOS provides a Keyhole Markup Language (KML) document containing color-coded asset weather impacts at one or more layers. These layers are comprised of one or more horizontal grid cells representing the impact condition within each cell.

The grid cell impacts created by the RES are passed to the IOS which, in turn, creates an overlay document. An example overlay is a single layer of 20 × 20 grid cells with a horizontal dimension of 5 km per side, thus covering a 100 × 100 km region. The document will typically be used to visualize the spatial impacts in a 2-D (*32*) and/or 3-D (*33*) geospatial viewer. Note that the service is generic enough, that it can represent any type of impact for display, not necessarily an atmospheric impact.

After the service receives an OverlayLayer array, it will compute and return the impact information as an overlay document. Each impact is represented by four bits and a total of 16 impact levels (0-f), hence 16 colors can be represented. See figure 3 for a simple example of a two layer impact display in Google Earth from the returned IOS string.

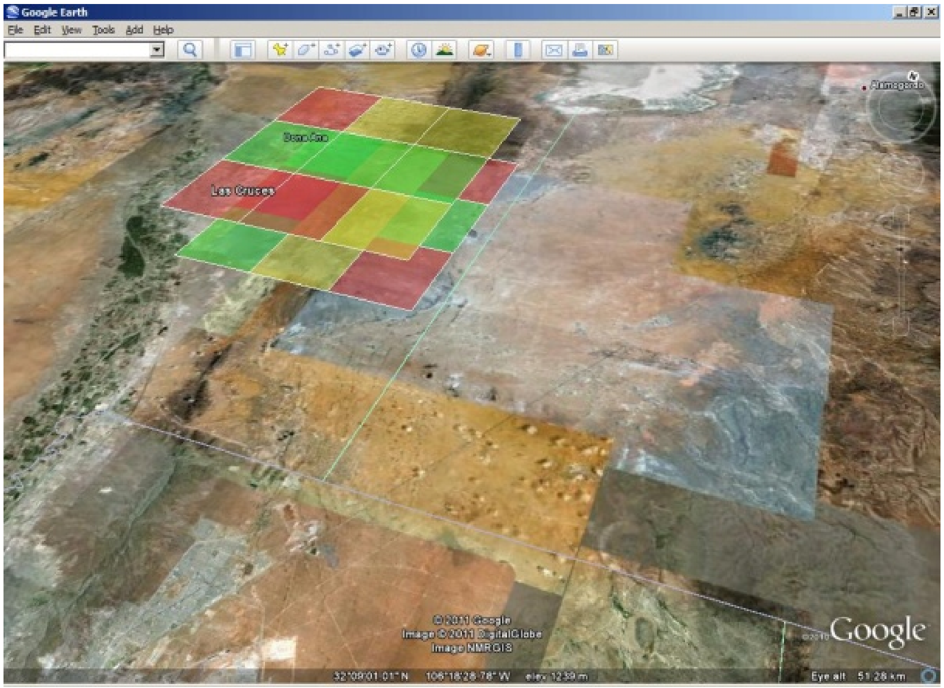

Figure 3. Two layer impact display in Google Earth from the returned IOS string.

In the context of MyWIDA, an impact represents the severity of an environmental effect on a military asset (e.g., a weapon system, personnel, etc.). The MyWIDA paradigm currently supports three levels of severity: no impact, marginal impact, and severe impact, which are represented by the colors green, amber, and red, respectively. The overlay document consists of the latitude, longitude, elevation, color and transparency, and ID for each cell. In addition, the document includes an asset name (e.g., AH-64 Impacts) and description (e.g., icing at 5000 ft mean sea level [MSL]) for the overlay. A user may request one or more layers in a single cell, and each layer may represent a different asset and/or elevation.

The IOS includes the following method: getOverlay returns a KML document given an impact grid, height MSL grid, color definitions, and descriptive label.

5.5 Automated Impacts Routing

Atmospheric impacts on platforms and alternative routing options, which consider environmental factors along a planned path of movement, are of high importance during combat operations. Such options serve to improve survivability and movement efficiency of air and ground platforms and systems. Environmental factors, which may adversely affect systems during combat operations along a projected path, include adverse weather, threat activity, conflicting friendly operations, and other obstacles. ARL/BE has developed the AIR application (*34*), which calculates optimized routes in 3-D space, avoiding adverse atmospheric conditions and other obstacles during mission execution. AIR has been developed as both a stand-alone desktop application (execution without a web server), as well as a web service. The web service version

of AIR is what can be directly accessed from the MyWIDA web services (or other web services).[††] AIR, though not an integral part of the impacts calculations, acts as an add-on to the MyWIDA services and allows path optimization through adverse impact grids that are generated by MyWIDA.

AIR can ingest any data type as a 3-D grid of "impacts," and one such data type is weather impacts. Impact values for weather are determined by sets of platform-specific rules, which are described in detail in section 3. The impact values that AIR is expecting are typically integers (as described as "Impact Code" in section 3), but an integer type is not a necessary input requirement for AIR. MyWIDA can generate 3-D weather impacts (integers) grids for various platforms, coupling the operational characteristics of the platform with the weather conditions at every data point in a 3-D grid (e.g., forecast data). The resulting 3-D grid of impacts can then be fed into AIR, with additional user inputs, described below.

When an AIR web service operation is called, the user request includes 3-D-gridded impacts data (with or without 3-D obstacles/volumes of avoidance); waypoints required along the path of movement (number of waypoints in the request is not bounded, and only limited by hardware); speed at each waypoint (identifying speed along segment between required waypoints); and the level of "risk" for the resulting path, for which there are currently two options: a path of less risk or a path of more risk. For the "less risk" option, the impacts data are weighted more heavily, whereas for the "more risk" option, the movement costs are higher than other factors. As a result, if one is willing to traverse higher risk areas, one can possibly have a shorter path, both spatially and temporally, to arrive at the goal node in a route.

An example showing low-/high-risk path results from AIR is shown in figure 4.

[††] Johnson (*36*) provides additional details for the web service application and stand-alone desktop application AIR packages.

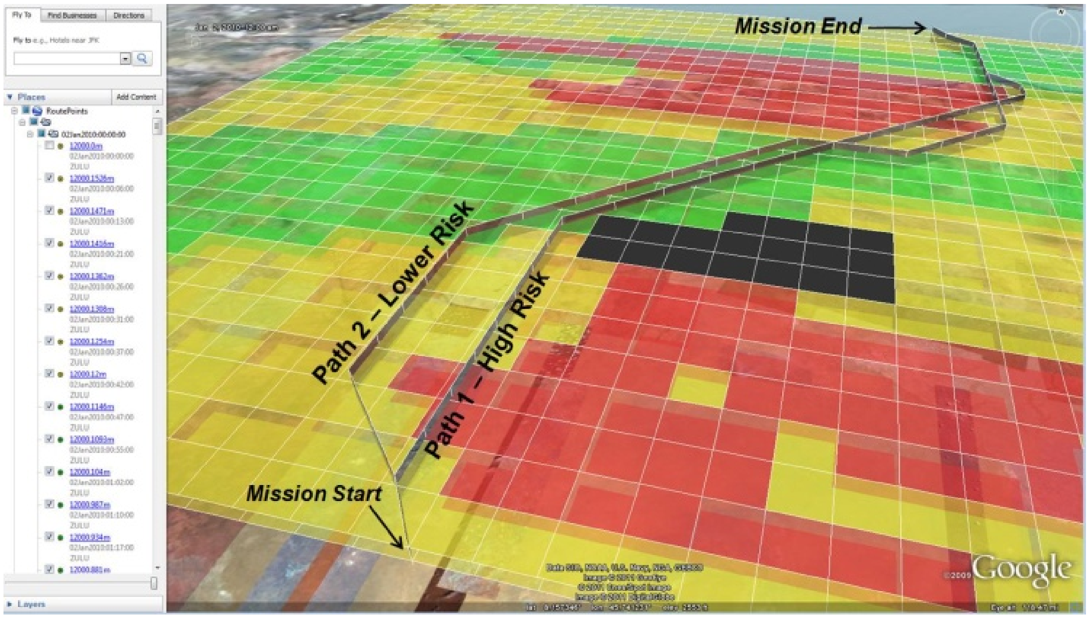

Figure 4. AIR KML output showing different path options as a result of different user risk-level requests.

5.5.1 Verification and Validation

The AIR web service has been verified to operate asynchronously (i.e., accept and solve multiple requests simultaneously) (figure 5). The implementation of the path-finding algorithm and the results has been verified through vigorous testing and analysis. By design, the resultant path that AIR obtains is limited only by the accuracy of the impacts data ingested by it. For example, if the forecast data are incorrect, the resulting optimized path through the forecast data may not match what is “best,” only because the input data were not accurate. For the A* algorithm, the algorithm itself has been verified and validated by its wide use in industry (*35*), as well as the gaming community. The implementation of the A* algorithm into AIR is also using verified and validated data structures and other algorithms associated with the Java Development Kit (JDK) 6.0, which is a well-established programming language.

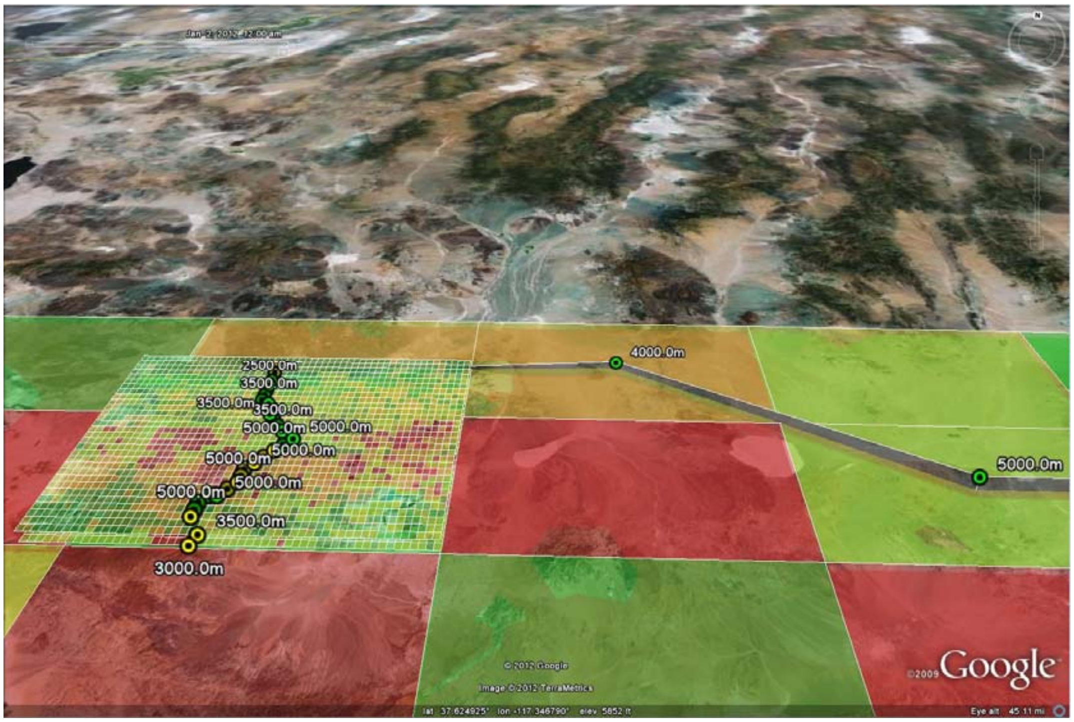

Figure 5. Asynchronous path optimization at multiple spatial and temporal resolutions.

6. MyWida: a Reference Implementation

MyWida is a reference implementation for GEN II Weather Impact Decision Aid services. It provides a unified GEN II application from which the user can do the following:

- Specify a set of assets and their associated rules.
- Select any forecast model run available from the AOIS.
- Choose specific assets, forecast periods, and layers.
- Evaluate the selected assets for the selected forecast periods and layers, using the RES.
- Display the resulting weather effects impacts in the following forms: tabular or 2-D or 3-D map overlay, provided as a KML document from the IOS.
- Query for the specific rules and forecast parameter values causing an impact at a given layer and location.

The implementation, as shown in figure 6, consists of the following:

- A Java Application Programming Interface (API) suitable for incorporation of MyWida into a custom GUI or as part of another application.

- A servlet for deployment of the API as a stand-alone web application with two associated browser options: an Adobe Flash‡‡ version and a standard HTML/Javascript version requiring no additional browser plug-ins.

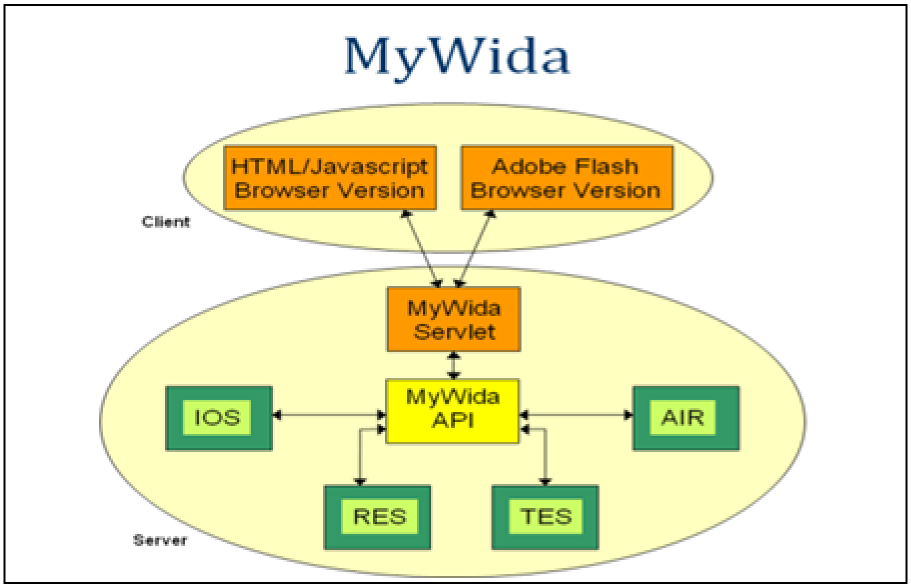

Figure 6. MyWida API, servlet, and browser architecture within GEN II.

These various implementations will be discussed further in the following sections.

6.1 Java API

The API functionality (defined by the class MyWida.java, contained in the package arl.wx.mwapi) is listed below:

- setRules–Specify a set of assets and their associated rules, as described in section 3.2.
- getAOIs–Obtain descriptions of the currently-available meteorological forecast model run data, based on the data provided by the TES getGridInfo function (c.f. 5.1.2).
- evaluateAssets–Provide an array of weather impacts for specified assets, forecasts, and layers. The array consists of a set of rows, representing assets, and columns, representing forecast times. The intersecting values within the array represent the maximum impact over the entire AOI and among all specified layers for that asset and forecast time.
- getOverlay–Generate a KML document depicting a 2-D or 3-D overlay of impacts for the specified asset, forecast, and layers. A 2-D overlay will represent the highest impact among the specified layers, whereas a 3-D overlay will provide a separate overlay for each layer.

‡‡ Adobe Flash is a registered trademark of Adobe Systems Incorporated.

- getCellImpacts–Obtain the marginal and unfavorable impact rules and meteorological parameter values for a specific asset and forecast at a specific layer and horizontal location within the AOI.
- getParameterValues–Obtain the values of the requested meteorological parameters for a specified layer and horizontal location within the AOI.
- optimizeRoute–Generate a route through the specified points, optimized to minimize weather impacts.

Within MyWida, access to the GEN II services is provided through the classes RESPort, TESPort, IOSPort, and AIRPort. These port classes extend the associated Java Architecture for XML (JAX) and JAX Binding (JAXB)-generated javax.xml.ws.Service classes RuleEvaluationService, ThresholdEvaluationService, ImpactOverlayService, and AIR_Service. As with the MyWida schema classes, these port classes manage the associated service WSDL ports and operations, freeing the implementation classes from tedious aspects of service and port management.

6.2 MyWida Servlet

The MyWIDA servlet provides the API with an HTTP interface, using "POST" and "GET" requests. All data are contained in XML documents. Object-XML translations are performed using Asynchronous Java and XML (AJAX) on the client and JAX on the server. Each client session, consisting of a separate browser window, contains its own instance of the JAVA API, so that the servlet can support any number of simultaneous, asynchronous clients.

Each "POST" or "GET" request contains two fields: operation and ID. The ID field contains a unique identifier generated by the client at initialization and remains constant for the duration of the client session. This allows the server to support multiple client sessions. The operation field contains one of the following values: init, setAssetList, evaluateAssets, getAIOInfo, getOverlay, optimizeRoute, and getCellImpacts.

The following HTTP requests are made to the MyWIDA servlet during the navigation of the application:

- Initialize MyWIDA–During the startup of the application, a "POST" request is sent to the servlet using the "init" operation. This initializes the server MyWida application for the specified session.
- Retrieve Areas of Interest–After the MyWIDA application has been initialized correctly, a "GET" request is automatically sent to the servlet using the "getAOIs." The request returns data about the available AOI(s), including layers and forecast periods.

- Import Rules–When a client imports a rule file, a “POST” request is sent to the servlet using the “setRules” operation, along with the user’s imported rules file. This request returns a list of assets associated with the imported rules.
- Calculate Impacts–When the client initiates an impact calculation, a “POST” request is sent to the servlet using the “evaluateAssets” operation. All the information concerning the selected AOI along with each specific layer, asset, and forecast period are sent in this request. The request returns data about the color-coded impacts for each selected asset and forecast period.
- Display KML Map Overlay (2-D via OpenLayers and/or 3-D via Google Earth)–When the client requests a map overlay, a “POST” request is sent to the servlet using the “getOverlay” operation. The request contains the asset name and the forecast period, and specifies whether the overlay should be 2-D or 3-D. This request returns a KML document depicting the impact overlay.
- Retrieve Cell Impact Rules–When the client request detailed impact information for a specific cell location in the impact grid, a “POST” request is sent to the servlet using the “getCellImpacts” operation. This request returns information about the layers and rules that were activated during the calculation of the impacts at the specific grid.

6.3 MyWida Graphical User Interfaces

In order to successfully run the MyWIDA application, the Hyper Structured Query Language (HSQL) data base server must be running and the RES, TES, IOS and AOIS web services must be deployed on an application server such as Glassfish or Jboss along with the MyWIDA flex application. Also Google Earth should be installed locally if the user wants to view the impacts as a 3-D map overlay. Due to the requirements of OpenLayers, the application runs the best in the Firefox web browser.

6.3.1 HTML and Javascript

This GUI is based entirely on HTML and Javascript, requiring no browser plug-ins. Most of the HTTP “POST” and “GET” requests are generated using AJAX, with the exception of the getOverlay operation, which uses an OpenLayers extension of AJAX and the setRules operation, which uses a simple HTML form element. This is returned using a hidden iframe (inline frame), so that the entire page will not be rendered again. All data are transferred between client and server via XML, with the exception of the rules file, which is in simple comma separated variable (CSV) format

6.3.2 Adobe Flex

A secondary MyWIDA GUI was developed using Adobe Flex. Flex is an application framework that makes the ability to easily build internet applications, which run inside the internet browser using Adobe Flash Player. The Flex software development kit (SDK) includes ActionScript and

Macromedia fleX Markup Language (MXML) layout along with the Flex framework. The Flex SDK was used to build the user interface of the MyWIDA application.

Flex applications are stateful, which means that once a Flex application is loaded it remains running as long as the application is in use. Thus, it does not completely reload when items are selected or clicked on. This reduces hits to the web server, application server, data base, and network. Requests are made back and forth between the application and server only as data are needed.

All requests are generated by Flex and sent in XML to the servlet. When data become available, Flex interprets the servlet's XML response, and it is automatically displayed in the MyWIDA application. Also, the application is wrapped with JavaScript only to display the 2-D map overlay via OpenLayers, similar to the HTML version of the MyWIDA web application as described in section 7.2.1.

7. Space Weather

As defined by the American Meteorological Society "space weather" refers to conditions on the sun and in the solar wind, magnetosphere, ionosphere, and thermosphere that can influence the performance and reliability of space-borne and ground-based technological systems and can endanger human life or health. These space weather phenomena have a variety of effects on technology. Energetic particles emitted from the sun interact with the earth's magnetic field producing magnetic disturbances and increased ionization in the ionosphere, from 100 to 1000 km above the earth.

Sunspots are the most common indication of solar activity with larger and more complex sunspot groups having greater potential for instability resulting in numerous solar flares and prominences or coronal mass ejections. Researchers have noticed that during a period of about 11 years the number of sunspots increases from almost none to more than 100, and then the frequency of sunspots slowly declines to near zero again, beginning a new cycle. Sunspot maxima correspond generally to periods of high solar activity. This activity includes increased solar wind and phenomena like aurorae and magnetic storms that are correlated with the solar wind, increased flares and prominences, and increased nonthermal radio and x-ray emission. Conversely, near sunspot minima, the Sun is much quieter with respect to these phenomena.

Global Positioning System (GPS) receivers use radio signals from several orbiting satellites to determine the distance from each satellite and subsequently determine the actual position of the receiver. As these radio waves pass through the ionosphere, they are subjected to variations in the electron density structure of the ionosphere. Space weather activity can change the electron density, which in turn can change the speed at which the radio waves travel, introducing a "propagation delay" in the GPS signal. The propagation delay can vary from minute to minute,

and such intervals of rapid change can last for several hours, especially in the polar and auroral regions. Changing propagation delays cause errors in the determination of the distance commonly referred to as “range errors.”

Space weather not only effects GPS but also High Frequency (HF) communications, Ultra-High Frequency (UHF) Satellite Communications (SATCOM), Satellite Operations/Health, Space Object Tracking/Satellite Drag, High-Altitude Flight, and Radar Interference/Anomalous Returns. AFWA has constructed a comprehensive web site for the effects and impacts of space weather on the aforementioned categories. The web site, which requires a Common Access Card (CAC) and a .mil address is located at https://weather.af.mil/AFW_WEBS/. In the following sections, a brief summation is presented of the information that may be found on the “space weather products” link under “Project Manager” on the home page.

7.1 Space Weather Events and Impacts Stoplight Chart

The space weather events and impacts stoplight chart is presented in figure 7.

The left portion of the figure represents type of activity, probable impacts, and reported impacts that were observed in the last 14 d. This portion is only updated for the 00Z product. The right portion of the figure shows the forecast for the next 3 d and is usually updated during the 18Z forecast, when most of the new data are available to the forecast center. The center columns represent the observed (“O”) and Forecasted (“F”) conditions for the current day. It is updated throughout the day. The top portion of this figure reports the space weather events that could cause impacts to operations, such as solar flares/radio bursts, energetic particles, or geomagnetic storming. An explanation of these categories follows.

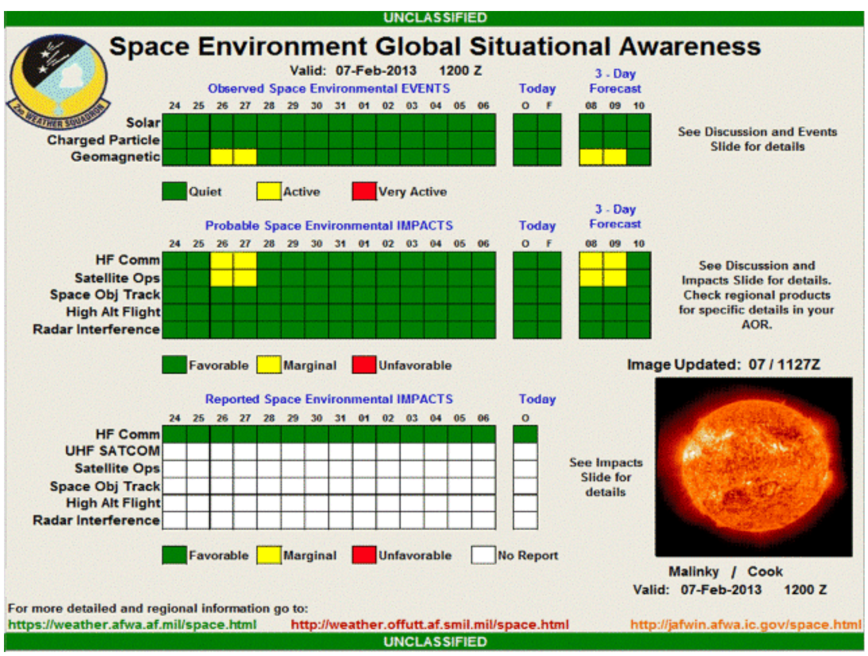

Figure 7. Space weather events and impacts stoplight chart from AFW-WEBS.

7.1.1 Solar Activity

This category shows the overall activity level of the sun and its likelihood to impact systems. Criteria analyzed to determine the state of this category are the occurrence of moderate or greater x-ray flares and significant solar radio bursts.

7.1.2 Charged Particle Environment

This category shows the observed or forecast potential for system impacts from charged particles significantly above normal background levels. Charged particle enhancements occur due to solar events or enhanced geomagnetic activity.

7.1.3 Geomagnetic Activity

This category shows the overall geomagnetic activity level of the Earth's magnetic field. A measured or forecast planetary geomagnetic activity index is used to determine the likelihood of system impacts. The middle portion of this slide reports probable (unconfirmed) space environment impacts to five major categories of space related operations. These include (1) HF communications, (2) Satellite Ops/Health, (3) Space Object Tracking/Satellite Drag, (4) High-Altitude Flight, and (5) Radar Interference/Anomalous Returns. The bottom portion of the slide highlights reported space environment impacts from users. It is divided into six categories: the five from above and UHF SATCOM communications.

7.1.4 HF Communications

This category depicts degradation of HF communications due to changes in the ionosphere, where long-range HF signals are usually reflected. Moderate or greater solar flares are considered in assessing the observed and forecast conditions. These solar flares emit x rays, which enhance the lower levels of the ionosphere resulting in absorption of HF signals. Solar flares usually affect the lower portion of the HF spectrum but can blackout the entire spectrum if sufficiently energetic. Also considered in assessing or forecasting HF communications is the level of geomagnetic activity. Strong geomagnetic activity often results in a decrease in the ionosphere's ability to reflect HF signals. Strong geomagnetic activity also leads to enhanced aurora in the northern and southern high latitudes, which can significantly degrade HF communications.

7.1.5 UHF SATCOM Communications

This category depicts degradation of UHF SATCOM communications due to changes in the ionosphere. UHF signals are transmitted through the ionosphere ("transionospheric") for communications to satellites. UHF scintillation occurs mainly in the equatorial region and the auroral region. In the equatorial region, the greatest impacts usually occur just after local sunset to approximately 0200L and have a seasonal dependence. During quiet geomagnetic activity, the scintillation is usually stronger, with moderate to strong geomagnetic activity working to suppress the equatorial UHF scintillation. Strong geomagnetic activity also leads to enhanced

aurora in the northern and southern high latitudes, which can significantly degrade UHF communications

7.1.6 Satellite Operations/Health

This category depicts the potential for or observed degradation or damage to satellites themselves. This damage or degradation usually results from particle interactions with the spacecraft. Particles can deposit electrical charge on or within a spacecraft and cause damage through a discharge, or they can damage the satellite through collision or by overwhelming or disorienting the satellite's sensors. Information considered in determining the state of this category are the number and energy of particles in the space environment; geomagnetic activity, which can enhance and accelerate particles in the space environment; and reported observations of satellite anomalies thought to be the result of the satellite environment.

7.1.7 Space Object Tracking/Satellite Drag

This category indicates the observed and forecast potential for unexpected changes in the orbits of satellites. Changes in satellite orbits result from an increase or decrease in the drag normally experienced at a satellite's orbit. This change in drag results from the heating or cooling of the upper atmosphere due to changes in the sun's radiation output or to geomagnetic activity.

7.1.8 High-Altitude Flight

This category indicates the maximum level of radiation exposure at an altitude of 67,000 ft. It will be YELLOW for dose rates greater than or equal to 3 mrem/h and RED for dose rates exceeding 30 mrem/h. This radiation is a product of cosmic rays from outside the solar system, as well as very high-energy protons occasionally produced by explosive events on the sun.

7.1.9 Radar Interference/Anomalous Returns

This category depicts observed and forecast degraded operation of radars used to track objects in space. Radio frequency bursts from the sun can cause interference to radars when the sun is in their field of view. Additionally, anomalous returns can occur when geomagnetic activity disturbs the ionosphere.

7.2 Additional Space Weather Products

Many other charts and figures can be found on the AFWA/space weather web site, to include the following:

- Daily indices−7 and 30 d trend
- High-altitude radiation dosage chart
- Worldwide analysis of ionospheric conditions impacting HF propagation applications
- Worldwide 6 h forecast of ionospheric conditions impacting hf propagation applications

- Worldwide 6 h forecast of ionospheric conditions impacting UHF SATCOM applications
- Worldwide estimated GPS single-frequency error map 2-D Nowcast
- Worldwide estimated GPS single-frequency error map 2-D Forecast
- Worldwide auroral boundary

Tutorials and links to other web sites for space weather are also presented.

8. Future Plans

In Fiscal Year (FY) 2014, GEN II/MyWIDA v4[§§] will implement data from additional weather forecast models, extend the range of its capabilities to include determination of risk levels for assets (*36*) and provide improved sensor impacts (*37*).

8.1 Additional Forecast Models

8.1.1 Unified Model

The Unified Model (UM), originally developed by the United Kingdom Met Office (UKMO), is under continual development, taking advantage of improved understanding of atmospheric processes and steadily increasing supercomputer power (*38*). Typically four forecast cycles are run per day with 0.25° resolution. The global grid size is 68 GB for all four cycles in a given day. AFWA is scheduled to transition to 20 km horizontal resolution grids.

8.1.2 Weather Running Estimate–Nowcast

The Weather Running Estimate−Nowcast (WRE-N) model uses the WRF with the ARW core; however, it differs from the WRF-ARW retrieved from AFWA in-so-far as it incorporates advanced data assimilation techniques. Furthermore WRE-N is currently being examined with various nested configurations. The output serves as input to the 3-D Wind Field (3DWF) diagnostic model (*37*). Research with WRE-N is ongoing as to the frequency/type of observations (such as the Tropospheric Airborne Meteorological Data Reporting (TAMDAR), surface, and radiosonde) that would optimize forecast capability as well as various nesting configurations and resolutions. Currently WRE-N is configurable down to 500 m.

8.1.3 Climatology

MyWIDA can currently ingest forecast data from various sources; however, there are times when obtaining a forecast is not possible. When this occurs, climatology becomes a viable option, that is climate accounts for all past weather events and for future climate predictions. If we assume that climate is not changing rapidly, then high-quality long-term climate data can tell us the

[§§] Version 3, considerably different from GEN II, was developed by Defense Common Ground System-Army Weather.

qualitative range of weather events we might expect in the future. For advance planning, or when forecasts may not be available, climatology is a reasonable option. Thus, MyWIDA v4 will allow for climatological access.

8.2 Transitions from Red to Green

MyWIDA's impacts are color-coded regions, currently a step function, and do not portray a continuum of values as would be expected in real-life transitions. To rectify this, MyWIDA will include a Parameter Weighting Scheme (PWS) (*36)*. The PWS capability will allow the MyWIDA user to focus on the most critical weather parameters affecting mission success based on the forecast weather situation, tactical scenario, and mission profile by choosing the most mission-critical parameters and assigning relative weights according to their importance on operations. The inclusion of the PWS capability will provide granulated impacts due to adverse weather conditions, and, thus, better represent the "stoplight code" continuum.

8.3 Infrared Sensors

Environmental effects on infrared sensors will be addressed in a unified approach by employing the Target Acquisition Weapons Software (TAWS) (*40*) in conjunction with MyWIDA. TAWS was designed to provide detection, recognition, identification, and lock-on range predictions for sensors and targets under various weather conditions. Because MyWIDA does not contain any targets or sensors, a methodology was developed to overcome those limitations (*37*). TAWS was run over various targets and weather conditions using all IR sensors and then averaged those results over subsets of the weather and target parameters. The final results were 116 parametric curves determining detection range as a function of visibility. These curves will be examined for inclusion into MyWIDA.

8.4 Point forecast

Occasionally the only weather data available will be from a point observation or from a TAF. The resulting output is therefore limited only to the geographic location (point) for which the weather forecast was entered. The capability to manually enter this information will be incorporated into MyWIDA in the next version.

9. Conclusions

GEN II/MyWIDA, an expert rules-based tactical decision aid, provides weather effects on numerous military systems (friendly and threat) in the form of a WEM with associated stop-light charts overlaid on map backgrounds. The WEM and map overlay may be interrogated further to obtain information on why a system has been flagged as having a severe or moderate impact. Rules, supplied in a delimited Excel file, may be easily modified or added to by the user and are saved locally for further usage.

GEN II includes the AIR web service application, which allows the determination of a least-cost path across multiple waypoints and determines this path based on a 3-D grid of impacts, regardless of the impact type. AIR also provides a mechanism to identify 3-D obstacles when calculating a path, allowing identification of exclusion volumes due to no-fly zones, buildings, terrain, friendly/threat operations, or other user-defined conditions. AIR can receive impact grids from MyWIDA or other applications, which can supply grids of impacts (weather or nonweather).

Both GEN II and AIR may be run as a web service or as stand-alone applications providing the user with multiple paths for implementation.

10. References

1. *Weather Effects and Information Handbook (Draft)*, U.S. Army Intelligence Center and School, Ft. Huachuca, AZ, 1988.

2. Dudenhoeffer, A. W.; Lee, R. R. *Documentation Report and User's Guide for Program TWEM (Tactical Weather Effects Messages)*; CR-88-0034-1; Atmospheric Sciences Laboratory, August 1988.

3. Petzko, D. R.; Powlette, D. D.; Rice, J. E. *Consolidated Weather Effects Decision Aid, Volume 1*; CR-90-0008-1; Atmospheric Sciences Laboratory, March 1990.

4. Maunz, W. G.; Chesley, C. H.; Spillane, A. R.; Eure, S. L.; Shaw, P. J. *Engineering Plan of the Integrated Weather Effects Decision Aids (IWEDA) Software Program*; TR-2582; Science and Technology Corporation, April 1992.

5. Lee, R. R.; Bussells, S. E. The Integrated Weather Effects Decision Aid: A New Planning Tool. *Proceedings of the 1992 Battlefield Atmospherics Conference*, 1992; pp. 501−509.

6. Chesley, C. H.; Johnson, J. S.; Maunz, W. G.; Spillane, A. R. Integrated Weather Effects Decision Aid (IWEDA). *Proceedings of the 1993 Battlefield Atmospheric Conference*, 1993; pp. 451−458.

7. Sauter, D. P. *The Integrated Weather Effects Decision Aid (IWEDA): Status and Future Plans*; TR-2938; NRAD: December 1996; pp. 75−78.

8. Sauter, D. P. *IWEDA for Brigade Task Force XXI: Assessment and Lessons Learned*; TR-2989; SPAWAR: March 1998; pp. 53−58.

9. Torres, M. A. *DIRECT: Dynamic IWEDA Rule Editor and Database Control Tool*; TR-2989; SPAWAR: March 1998; pp. 59−64.

10. Sauter, D.; Torres, M.; Brandt, J.; McGee, S. The Integrated Weather Effects Decision Aid: A Common Software Tool to Assist in Command and Control Decision Making, Proceedings of the 1999 Command and Control Research and Technology Symposium, U.S. Naval War College, Rhode Island Newport, Rhode Island. 29 June–1 July, 1999. http://www.dodccrp.org/html4/events_past.html#1999.

11. Chesley, C. H.; Grocki, V. P. *Verification and Validation of Current IWEDA Rules, Science and Technology Corporation*; Technical Report 3157, December 1997.

12. Szymber, R. J. *U.S. Army Tactical Weather and Environmental Data Requirements, Critical Threshold Values and Impacts on Operations and Systems, and the Integrated Weather Effects Decision Aids (IWEDA) Rules*; ARL-TR-4672; Army Research Laboratory, December 2008.

13. Knapp, D.; Raby, J.; Measure, E.; Brown, R.; Gupta, V. A Weather Decision Aid For Unmanned Aerial Vehicle Missions. Twelfth Conf. on Aviation, Range, and Aerospace Meteorology, Atlanta, GA. Amer. Meteor. Soc., 2006.

14. Army Field Manual, FM 34-81-1, Battlefield Weather Effects, Headquarters, Department of the Army, 1992.

15. Mikkelsen, M. Private communication, 2012.

16. Szymber, R. J. Army Weather Effects Critical Values Database. Technical Document 2989, *Proceedings of the 1997 Battlespace Atmospherics Conference 2–4 December 1997*, pp. 259-264. Space and Naval Warfare Systems Center, San Diego, CA, March 1998 (K. D. Anderson and J. H. Richter, Editors), 1998.

17. United States Special Operations Command, 1998: Manual 525-6, Military Operations Critical Meteorological and Oceanographic Thresholds for SOF Operations. MacDill Air Force Base, FL, 13 March 1998.

18. Sauter, D. *My Weather Impact Decision Aid (MyWIDA) v1 User's Guide*; ARL-TR-5437; Army Research Laboratory, February 2011.

19. Global Forecast System. http://tornado.sfsu.edu/geosciences/classes/m698/NumericalWeatherPrediction/GFS.html.

20. The Weather Research and Forecasting Model. http://www.wrf-model.org/index.php.

21. NCAR Army Test Range Support. http://www.rap.ucar.edu/projects/armyrange/.

22. Use of MM5 in 4DWX. http://www.mmm.ucar.edu/people/davis/files/4dwx_mm5.html.

23. NCAR RTFDDA Model Visualization. http://www.ral.ucar.edu/projects/westafrica/rtfdda.php.

24. Passner, J. E. *The Atmospheric Sounding Program: An Analysis and Forecasting Tool for Weather Hazards on the Battlefield*; ARL-TR-1883; May 1999.

25. Passner, J. E. *Post-Processing for the Battlescale Forecast Model and Mesoscale Model Version 5*; ARL-TR-2988; June 2003.

26. User's Guide for the NMM Core of the Weather Research and Forecast (WRF) Modeling System Version 3 Chapter 7: Post Processing Utilities, users_guide_nmm_chap7.pdf, http://www.dtcenter.org/wrf-nmm/users/downloads/index.php.

27. User's Guide for the Advanced Research WRF (ARW) Modeling System Version 3.4, Chapter 9: Post-Processing Utilities (NCEP Unified Post Processor (UPP)), July 2012. http://www.mmm.ucar.edu/wrf/users/docs/user_guide_V3/users_guide_chap9.htm#UPP.

28. Blanchard, L.; Santee,W. *Comparison of USARIEM Heat Strain Decision Aid to Mobile Decision Aid and Standard Army Guidelines for Warm Weather Training*; USARIEM Technical Report T08-07, June 2008.

29. Sauter, D.; Zertuche, G. *Night Vision Goggles (NVG) Software User's Guide Version 5.1*; ARL-TR-524; June 1994.

30. Passner, J. E. *Using the Advanced Research Version of the Weather Research and Forecasting Model (WRF-ARW) to Forecast Turbulence at Small Scales*; ARL-TR-4575; September 2008.

31. NAVMETOCCOM Enterprise Architecture. https://itas.navo.navy.mil/JMCMS/models/.

32. OpenLayers. OpenLayers: Free Maps for the Web. http://openlayers.org/.

33. Google. Google Earth. http://www.google.com/earth/index.html.

34. Johnson, J. O. *Atmospheric Impacts Routing (AIR)*; ARL-TR-5792; November 2011.

35. Singh, S. The Mars Autonomy Project. http://www.frc.ri.cmu.edu/projects/mars/.

36. Szymber, R. J.; Jameson, T. C.; Knapp, D. I. A Parameter Weighting Scheme for an Automated Weather Effects Decision Aid. *J. Operational Meteorology* **2013**, *1* (8), 84−92.

37. Shirkey, R. C. *Determination of Risk Levels for Rule-Based Weather Decision Aids*; ARL-TR-4586; September 2008.

38. Met Office. Met Office Unified Model. http://www.metoffice.gov.uk/research/modelling-systems/unified-model.

39. Wang, Y.; Cionco, R. *Wind Profiles in Gentle Terrains and Vegetative Canopies for a Three-Dimensional Wind Field (3DWF) Model*; ARL-TR-4178; July 2007.

40. Shirkey, R. C.; Gouveia, M. Weather-Impact Decision Aids: Software to Help Plan Optimal Sensor and System Performance, CrossTalk. *The Journal of Defense Software Engineering*, December 2002.

List of Symbols, Abbreviations, and Acronyms

3-D	Three-dimensional
4-D	Four-dimensional
2-D	Two-dimensional
3DWF	Three-Dimensional Wind Field
4DWX	Four-Dimensional Weather
AFWA	Air Force Weather Agency
AIR	Automated Impacts Routing
AJAX	Asynchronous Java and XML
AKO	Army Knowledge Online
AOI	Area Of Interest
AOI app	Area Of Interest application
AOIS	Area Of Interest Service
API	Application Programming Interface
ARL	Army Research laboratory
ARW	Advanced Research WRF
ATEC	Army Test and Evaluation Command
AWRT	Aviation Weather Routing Tool
BED	Battlefield Environment Division
BFA	Battlefield Functional Area
CAC	Common Access Card
CRDB	Centralized Rules Data Base
CSV	Comma Separated Variable
DoD	Department of Defense
DPG	Dugway Proving Ground

FLIR	Forward Looking InfraRed
FM	Field Manual
GEN II	Generation 2
GFS	Global Forecast System
GMDB	Gridded Meteorological Data Base
GPS	Global Positioning System
GUI	Graphical User Interface
HF	High Frequency
HSQL	Hyper Structured Query Language
HTML	HyperText Markup Language
HTTP	HyperText Transfer Protocol
ID	Identifier
IMETS	Integrated Meteorological System
IOS	Impact Overlay Service
IWEDA	Integrated Weather Effects Decision Aid
JAX	Java Architecture for XML
JAXB	Java Architecture for XML Binding
JDK	Java Development Kit
JMB	Joint METOC Board
JME	Joint METOC Effects
JSP	JavaServer Pages
KML	Keyhole Markup Language
METOC	METeorological and Oceanographic
MM5	Fifth-Generation Mesoscale Model
MSL	mean sea level
MXML	Macromedia fleX Markup Language
MyWIDA	My Weather Impacts Decision Aid

NCAR	National Center for Atmospheric Research
NCEP	National Centers for Environmental Prediction
NOAA	National Oceanic and Atmospheric Administration
NWP	Numerical Weather Prediction
PWS	Parameter Weighting Scheme
PM	Program Manager
RAL	Research Applications Laboratory
REA	Rules Encoding Application
RES	Rule Evaluation Service
RR	Rules Repository
RT-FDDA	Real-Time Four-Dimensional Data Assimilation
SATCOM	Satellite Communications
SDK	Software Development Kit
SOAP	Simple Object Access Protocol
STC	Science and Technology Corporation
TADS	Target Acquisition and Designation Sights
TAMDAR	Tropospheric Airborne Meteorological Data Reporting
TAWS	Target Acquisition Weapons Software
TECD	Technology Enabled Capability Demonstration
TES	Threshold Evaluation Service
TM	Technical Manual
TRADOC	Training and Doctrine Command
UKMO	United Kingdom Meteorological Office
UHF	Ultra-High Frequency
UM	Unified Model
v	version
WEM	Weather Effects Matrix

WRE	Weather Running Estimate
WRF	Weather Research and Forecasting
WSDL	Web Service Description Language
WSMR	White Sands Missile Range
XML	Extensible Markup Language

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